NTD Germanium Microcalorimeter Development For Constellation-X

SAO / LBNL

FST Meeting
September 18, 2002

Discussion Topics

- Review Program For Array Development

- Progress Toward 4-Pixel Demonstration

  Readout electronics complete and tested

- Plans For FY2003

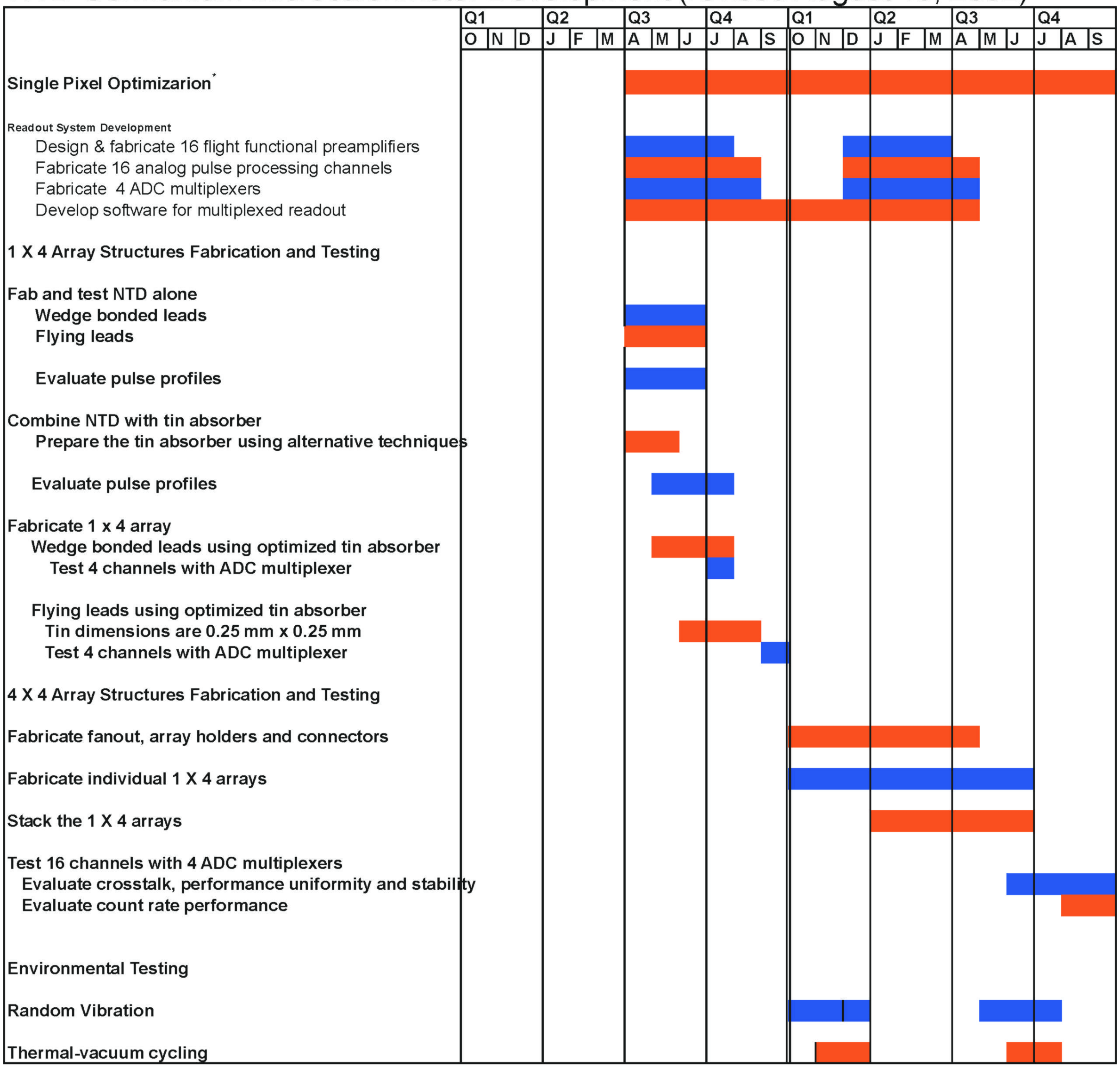
Status of SAO NTD Microcalorimeter Development
September 18, 2002

Single Pixel Microcalorimeter Properties

NTD thermistor:	250 µm × 70 µm × 50 µm 17 µm diameter aluminum wires
Tin absorber	0.4 mm × 0.4 mm × 7 µm 95% quantum efficiency at 6 keV
Energy resolution :	4.8 eV for energy band between 0.2 keV to 6 keV Dynamic noise is 3.1 eV

Application to *Laboratory Astrophysics* and *Materials Analysis* demonstrated by publications in Astrophysical Journal, Astrophysical Journal Letters, Physical Review E, Physica Scripta, X-Ray Spectrometry and Nuclear Instruments and Methods A.

NTD Germanium Microcalorimeter Development (revised August 13, 2002)



* Single pixel optimization is being carried out using SR&T funds

Pixel Evaluation and Testing Leading Up to 1 x 4-Pixel Array

● Revisit single pixel construction/fabrication before embarking on further array fabrication

Goal: performance of a single NTD thermistor with integrated aluminum leads must perform comparably to that of detector fabricated by hand, i.e., with wedge-bonded aluminum wires.

- ■ We are evaluating our techniques in a step-wise approach on single pixel devices

- ■ Tests with thermistors with integrated flying leads without tin absorbers
  - Test for contact noise: is power handling the same between types (we have had such problems with excess noise)

  - Test for temporal profile consistency: do we get the single exponential decay ?

- ■ Latest experimental run:
  - it finally looks like we may have solved most of the problems with new implants and slightly thicker leads
  - temporal profile looks comparable also

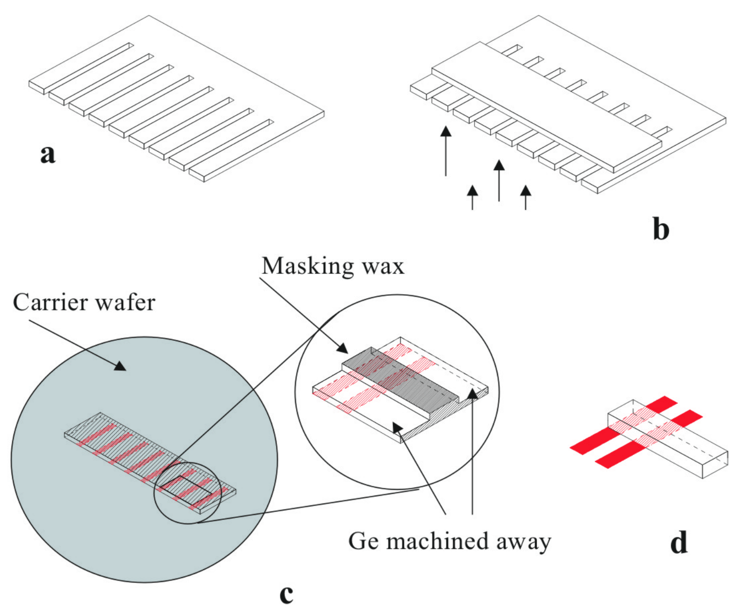
● Investigating the effects of impurities in the tin absorber to improve the reproducibility of the temporal response of the detectors. Microanalysis of the absorbers is being performed to evaluate the trace element concentrations

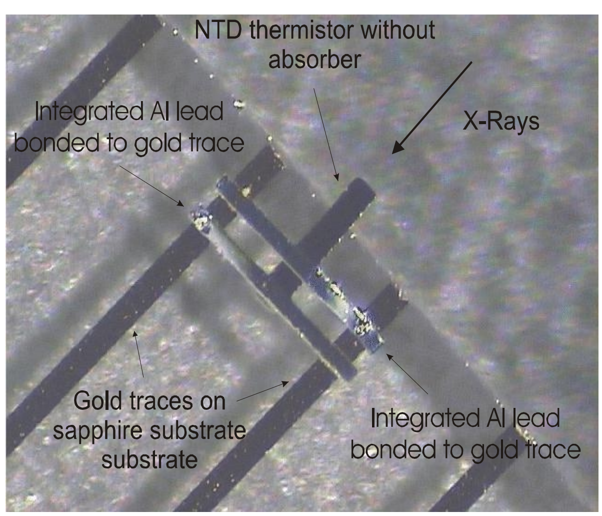
NTD-Ge MicrocalorimeterArrays

Two-dimensional array built up from series of stacked linear arrays

Three functional components

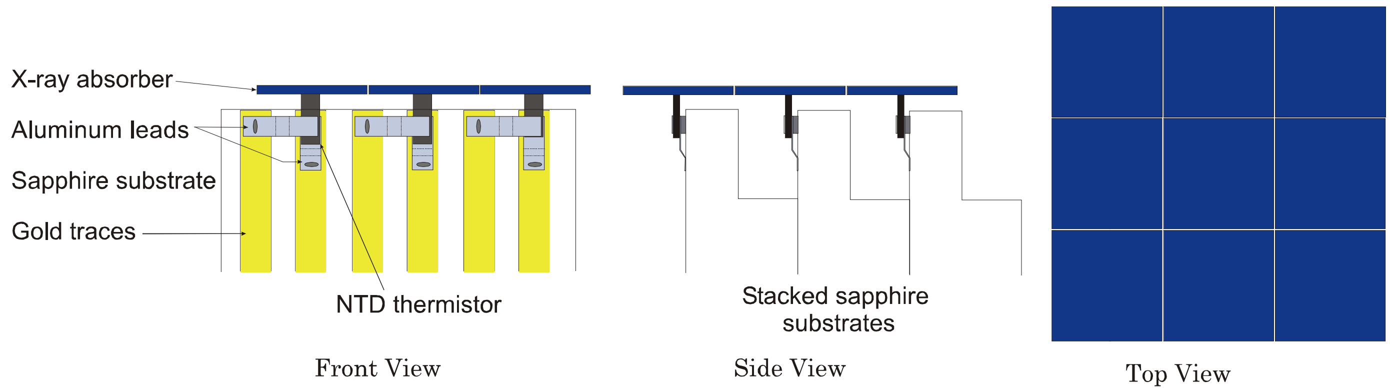
- a "micro-machined" NTD germanium thermistor with integral electrical leads;
- a sapphire signal wire fanout suitable for direct bonding of the thermistors;
- an x-ray absorber plate of proper composition and dimension.



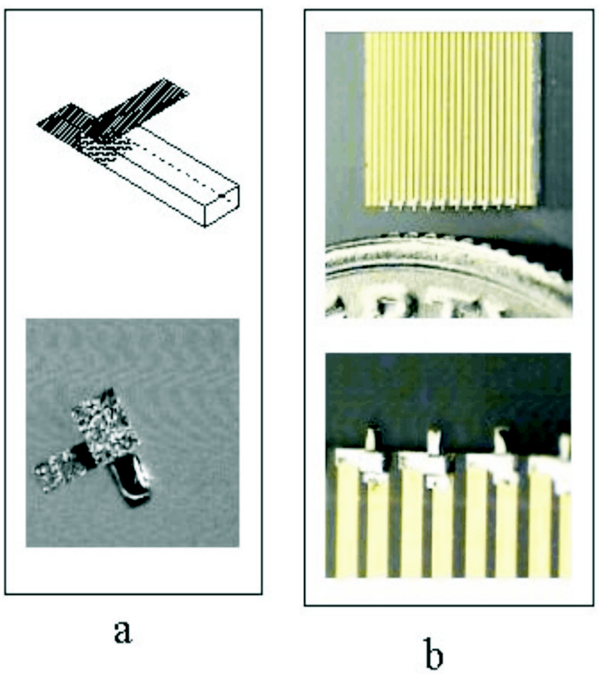


"Flying Lead Thermistor (Without Tin Absorber) Mounted to Sapphire Substrate.

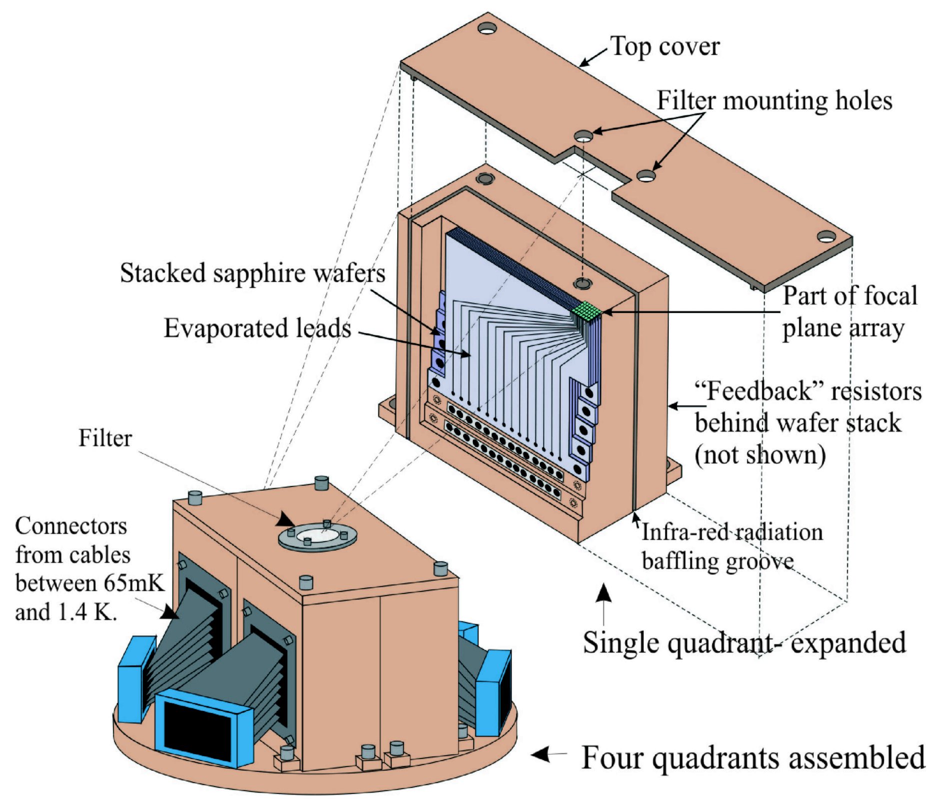
Schematic representation of a 3 x 3 array



Close-packing scheme for array.

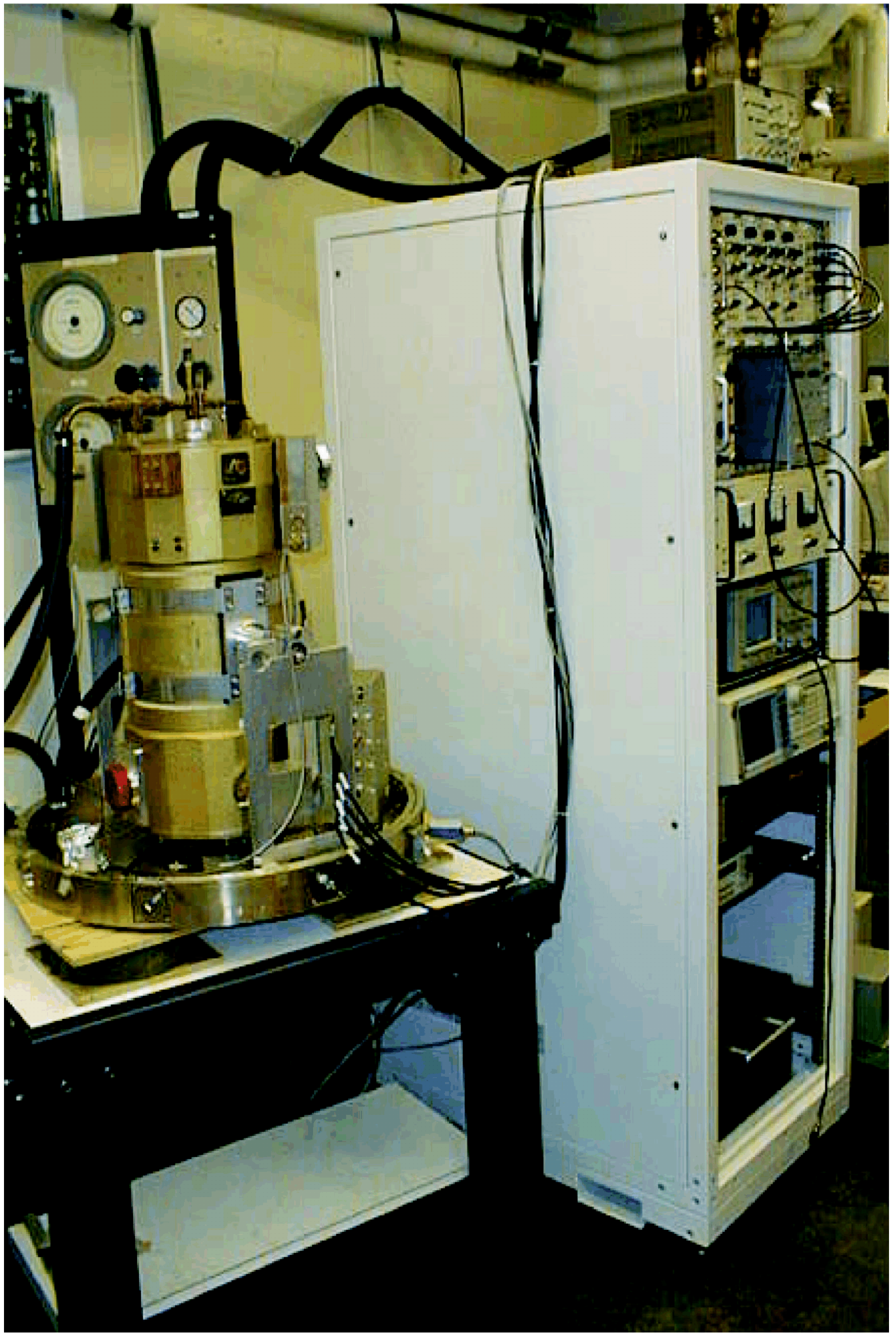


Opposing Surface Flying Lead Devices. a) Flying lead thermistor schematic and actual device, b) array of bonded chips next to a U.S. dime and a magnified view.

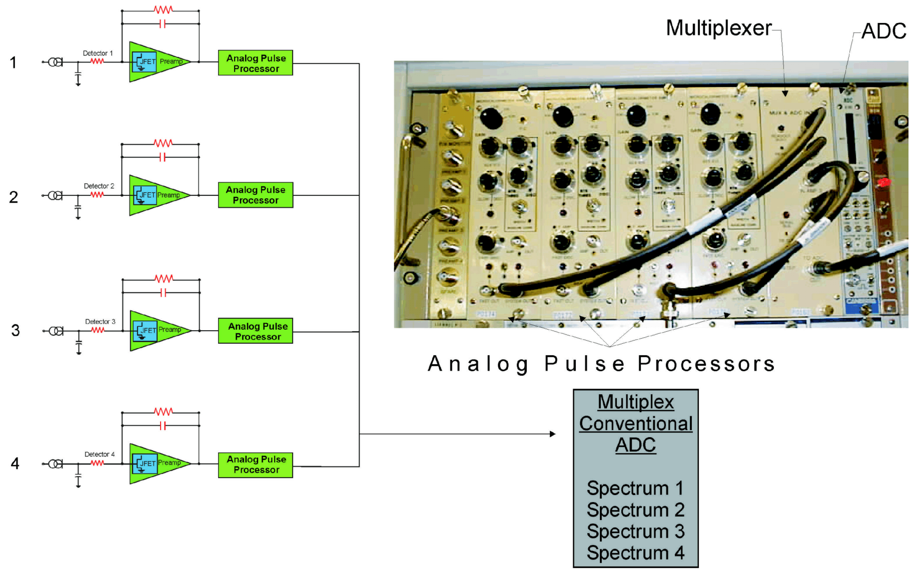


Modular nature of the array construction for flight

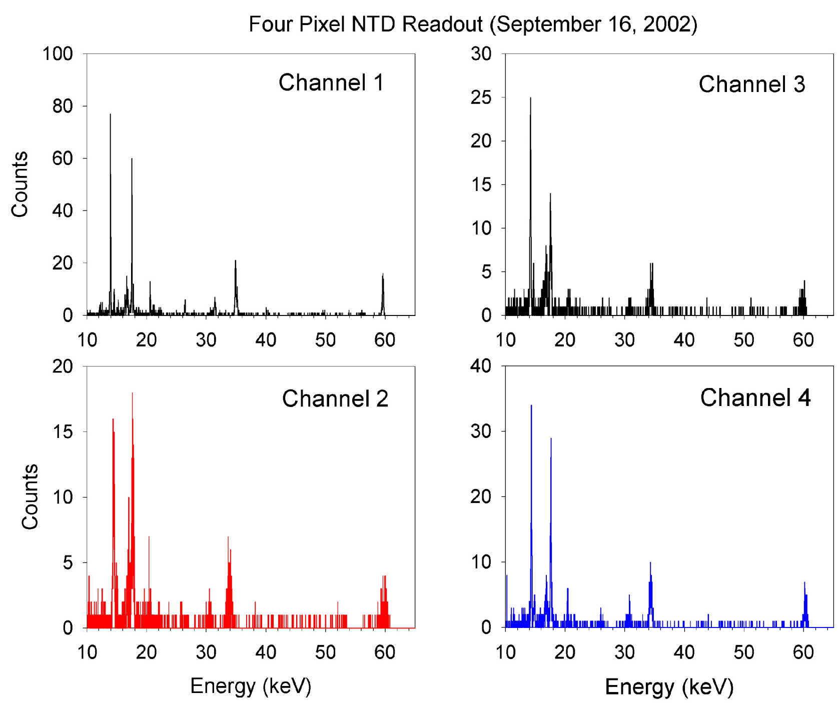
The prototype microcalorimeter system for testing the 1 x 4 array.



NTD Readout Electronics



A schematic of the 4 channel readout electronics (left) and a photograph of the completed modules used to record the spectra below.



Four spectra obtained simultaneously with detecttors optimized for the 10 keV to 60 keV band using the Constellation X NTD germanium electronic readout.

FY2003
Development Plan and Schedule

Single Pixel Optimization

a) Optimize (increase) resistance within constraints of negative voltage feedback (NVF) circuitry (reduces Johnson noise in NFV used in constant voltage configuration);

b) Adjust NTD thermistor geometry and doping to maximize α and minimize heat capacity;

c) Test devices to map out noise, especially 1/f, and responsivity;

d) Extend the operation of the proportional thermal baseline restoration system to entire 10 keV energy band (compatible with the constant voltage mode of microcalorimeter operation)

e) Determine performance at 1 KHz

f) X-ray absorber improvements - reduce absorber collecting area from 0.4 mm x 0.4 mm to 0.2 mm x 0.2 mm (CON-X requirement); laser cut absorbers; ramp up work on high Z, low heat capacity (high T_{Debye}) osmium

Array Structures Fabrication

4 x 4 array
With satisfactory outcome from 1 x 4 array, build 4 x 4 array by stacking four, 1 x 4 linear arrays

Design and fabricate fanouts and array holders with nano-connectors for each of the above array sizes.

Readout System Development

Fabricate remaining 8 analog pulse processing channels for testing 4 x 4 array in conventional electronic configuration.

Fabricate 2 remaining ADC multiplexers

Array Testing

Evaluate thermal and electrical crosstalk, performance uniformity and stability;

Evaluate performance of 10 Hz per pixel across the 16 channel array and at 1 KHz per pixel on a 2 x 2 subset of the array.

Environmental Testing of a 1 x 4 Array

Random vibration

Build a small fixture that will allow us to shake the microcalorimeter array at room temperature and at 4 K.

Thermal-vacuum cycling to evaluate mechanical and electrical integrity

a) 300K to 4 K : cycle temperature of array 60 times in a small helium cryostat ; test after every 20 cycles

b) 4 K to 60 mK: cycle temperature of array 60 times in a 2-stage ADR; test after every 20 cycles.